

Requirements, Justification and Implementation of the New TCU Design.
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The aim of this document is to explain and justify the re-design of the STAR Trigger Control Unit (TCU). There are four sections. The first is a list of requirements for the TCU functionality with their justification. Next there is a description of the original TCU implementation. This is followed by an explanation of where the original design did and did not meet each requirement and a list of additional problems that arose during the debugging and usage of this module. Finally there is a description of the proposed new implementation that should meet all the requirements, and solve the additional problems.

TCU Requirements

1. Requirement: **Format** - The TCU must be a 9U VME board.
Justification: All the DSM boards and TCD boards that provide input to the TCU are also 9U VME boards and this will enable it to fit easily into that system.
2. Requirement: **Speed** - The TCU must accept new input data every tick of the RHIC clock.
Justification: The DSM tree looks at data from the trigger detectors every tick of the RHIC clock, and presents it to the TCU, so the TCU must be able to receive it.
3. Requirement: **DSM Data** - The TCU must accept all the bits that the DSM tree can provide. Currently this is 16 bits.
Justification: The last DSM board can produce 32 output bits. These are split into two identical groups, one to go to the TCU and the other to go to the Scaler board. The maximum size of either group is therefore 16 bits.
4. Requirement: **Detector Status** - The TCU must accept a bit from each of the non-trigger detector systems indicating that system's LIVE/BUSY status.
Justification: The TCU is only supposed to issue triggers to detectors when they are LIVE
5. Requirement: **Internal BUSY** - The TCU must generate a short internal BUSY state for user-specified detectors to cover the time it takes between when the TCU issues a trigger to those detectors and when they send their BUSY states back to the TCU.
Justification: Again, the TCU is only supposed to issue triggers to detectors when they are LIVE, and if a trigger is issued to a detector at the end of one RHIC clock tick the TCU MUST know if that detector is supposed to be BUSY at the beginning of the very next tick.
6. Requirement: **Preceded** - The TCU must also be able to disable a detector (i.e. make it artificially BUSY) for a user-specified amount of time if the trigger detectors indicate the presence of contaminating data in the system.

Justification: The detectors do not want to be triggered if the triggered event will be contaminated by data from a preceding event that occurred so close in time to the triggered event that the two cannot be distinguished.

7. Requirement: **Followed** - If the trigger detectors indicate that a triggered event has been followed by another one within a user-specified amount of time then that information must be saved and made available to the outside world.

Justification: The user needs to decide whether or not to abort events that are followed too closely by another one.

8. Requirement: **Decision** - The TCU must issue triggers for events based on the information from the DSMs and which detectors are LIVE.

Justification: This is the only data that is available to the TCU on which to base a decision.

9. Requirement: **Downstream Resources** - The TCU should only issue a trigger if there are resources available in the rest of the trigger system to deal with it.

Justification: When a trigger is sent to the detectors it is also passed to the next level of the trigger system. That level is required to read out the DSM data that led to the trigger before it can be over-written. If there is no memory available to store the data, or no CPU available to initiate the reading, then the next trigger level will not be able to meet its requirements, so the TCU should not issue any triggers.

10. Requirement: **Prescale** - The TCU must be capable of triggering on a user-specified fraction of events of a given type.

Justification: Some event types are very common and can just be sampled. Others are very rare and every one should be triggered.

11. Requirement: **Detector Selection** - The TCU must be able to issue triggers to any subset of the existing detectors.

Justification: The detectors are not all interested in every trigger, even if they are all LIVE.

12. Requirement: **Notification** - When the TCU issues a trigger to any detector it must also make enough data available to the rest of the trigger system and DAQ so they know where to get the DSM data that led to the event, which detectors were triggered and what was the event type.

Justification: The later levels of the trigger system and DAQ need this information in order to read the data from the DSMs and to know which non-trigger detectors should be read out.

13. Requirement: **Halt** - The TCU must monitor the location, in the DSMs, of data for triggered events. If this data has not been read out by the time it is due to be over-written, then the TCU must halt the saving of new data in the DSMs, and halt issuing triggers, until the situation has been fixed.

Justification: Data is saved in the DSM circular input buffers for 7 ms after it is written. Data corresponding to events that were triggered must be read out within this time to make it possible to reconstruct why the event was triggered. If, for any reason, the next level of the trigger system does not manage to read out the data in time then the data would get over-written, and the reconstruction would not be possible.

14. Requirement: **Abort** - A mechanism must be provided to allow the later levels of the trigger system to abort an event that has previously been triggered.

Justification: The TCU makes its decisions based on a very simple analysis of the trigger detector data. The later levels of the trigger system have time to perform a more detailed analysis of this data. This analysis can show the event to be uninteresting, so there is no point in continuing to process it.

15. Requirement: **Null Event** - If the current event is not triggered, and there are no aborts to be issued, the TCU must actively send zeros to all the non-trigger detectors.

Justification: The detectors need to be able to determine when a trigger is being issued to them (either a new event, or an abort) and when they should do nothing.

16. Requirement: **Event Rate monitor** - The TCU must count how many events of each type it sees when it is LIVE (i.e. able to issue triggers) irrespective of whether or not a trigger is actually issued.

Justification: If the TCU is LIVE the reasons for not issuing a trigger are that no interesting interaction occurred, the non-trigger detectors are BUSY or that this event is not part of the user-specified fraction for this type (Requirement 10). By counting how many events of every type occurred, and comparing that to the number of events that were triggered (counted elsewhere in the trigger system) it will be possible to calculate relative event rates (part of the cross-section calculation), monitor the dead-time of the non-trigger detectors and monitor the TCU itself to see that the user-specified fractions have been specified correctly.

17. Requirement: **LIVE Monitor** - The TCU must count the number of RHIC clock ticks when it issues triggers, when it is LIVE but does not issue a trigger and when it is not LIVE.

Justification: This will enable us to monitor the performance of the TCU itself.